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ガスジェット浮遊を用いた Pt 融体の熱物性測定

Thermophysical properties of liquid platinum measured by aerodynamics levitation

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1. Introduction

In order to optimize various high temperature melt processes such as crystal growth of optical materials and additive manufacturing of complexly-shaped parts, accurate thermophysical properties data of high temperature melt such as the surface tension and viscosity are required. The electrostatic levitation (ESL) and electromagnetic levitation (EML) assure precisely measurement of thermophysical properties of high temperature melt due to absence of container wall that would be chemically reactive with the sample. However, it is difficult to investigate the effect of oxygen partial pressure (P_{O_2}) on surface tension of metallic melt in the ESL on the ground because this technique requires high vacuum condition to prevent a discharge from electrodes. Furthermore, the initial cost for installing the ESL is very expensive. On the other hand, only conductive materials can be used in the EML. Furthermore, the EML cannot measure the viscosity because Lorentz force which required levitating the droplet continuously excites the surface oscillation.

The aerodynamic levitation (ADL) technique allows levitation of all types of samples and P_{O_2} control. The initial cost for the installation is very low compared with the ESL and EML. The purpose of this study was to investigate the possibility for thermophysical properties measurement of high temperature melt by the ADL.

2. Experiment procedure

High purity platinum was used as a sample to eliminate the effect of oxidation and oxygen adsorption. A cube of the platinum was aerodynamically levitated by an argon gas jet from the bottom at a rate of ~900 mL/min. The levitated sample was heated by irradiation with the semiconductor laser. A monochromatic pyrometer was used to measure the temperature of the levitated droplet. After the platinum sample was completely melted, sound wave was applied to the gas jet prior to introduce in an ADL nozzle by two loudspeakers facing each other so that surface oscillation would be excited in the levitated droplet. Damping of the surface oscillation of the droplet was monitored by high-speed video camera after the sound wave was removed from the gas jet. The surface tension of liquid platinum was calculated from the frequency of the surface oscillation during the damping using the following Rayleigh equation[1).]

$$\sigma = \frac{3}{8}\pi M v_R^2 \quad (1)$$

where σ is the surface tension, M is the mass of the droplet, and v_R is the frequency of the surface oscillation. The viscosity of the sample calculated from the damping time from the following equation.

$$\eta = \frac{\rho r_0^2}{5\tau} \quad (2)$$

where η is the viscosity, and ρ is the density of the droplet, r_0 is the radius of the oscillation sphere, and τ is the damping time. The density of the droplet was calculated from the sample mass of solidified sample and the side view of the droplet, free from the excitation of surface oscillation, observed by HSV just after the nozzle was divided into two parts.

3. Result and Discussion

Figure 1 shows typical frequency spectra for difference of radii along the vertical and horizontal axes of projected droplet observed from above when the surface oscillation was excited to the levitated droplet maintained at ~2500 K using a sound wave from loudspeakers. When the frequency of sound wave for exciting the surface oscillation is varied from 180 to 210 Hz, the corresponding peaks are detected together with an additional peak at 193 Hz independent of those. Because the sample mass was constants, the peak detected at 193 Hz can be considered to be the natural resonant frequency of the surface oscillation.

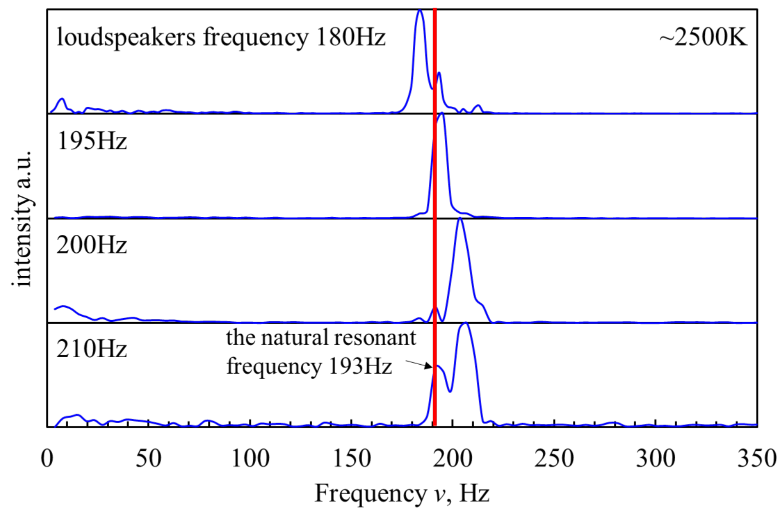

Figure 1. Typical frequency spectra for difference of radii along the vertical and horizontal axes of a projected droplet observed from above when surface oscillation excited by sound waves of different wavelengths from a loudspeaker on levitated droplet maintained at ~2500 K.

Figure 2 shows the surface tension of liquid platinum calculated from the natural resonant frequency determined by the above method using ADL, together with the measurement results by electromagnetic levitation (EML) and electrostatic levitation (ESL) for comparison. We successfully measure the surface tension up to very high temperature above 2800 K (●), far exceeding the maximum temperature in the reported data. The surface tension of liquid platinum measured by the ADL agrees well with those measured by EML (▲) and ESL(■, □[2])).

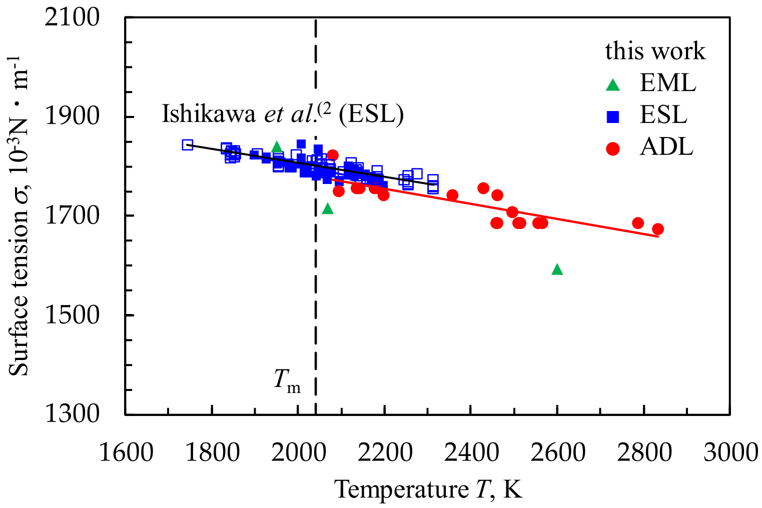

Figure 2. Surface tension of liquid platinum measured by ADL together with those by EML and ESL.

Figure 3 shows the viscosity of liquid platinum measured by the ADL in this study, along with those measured by ESL. The calculated result of the viscosity shows a relatively good agreement with the temperature dependence of viscosity of liquid platinum measured by ESL.

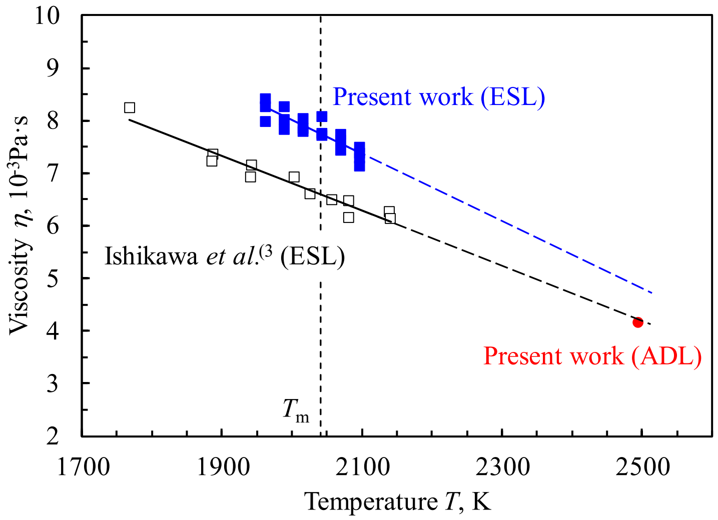

Figure 3. Viscosity of liquid platinum measured by ADL together with those by ESL.

Figure 4 depicts the density of liquid platinum evaluated from the sample mass and side view of droplet just after splitting the ADL nozzle. When the ADL nozzle was divided into two parts, the droplet free fell immediately and elongated in the direction of gravity. Assuming that the droplet is rotationally symmetric with respect to z axis parallel to the direction of gravity, the calculated density of the droplet is relatively agreed with the temperature dependence of the density measured by ESL.

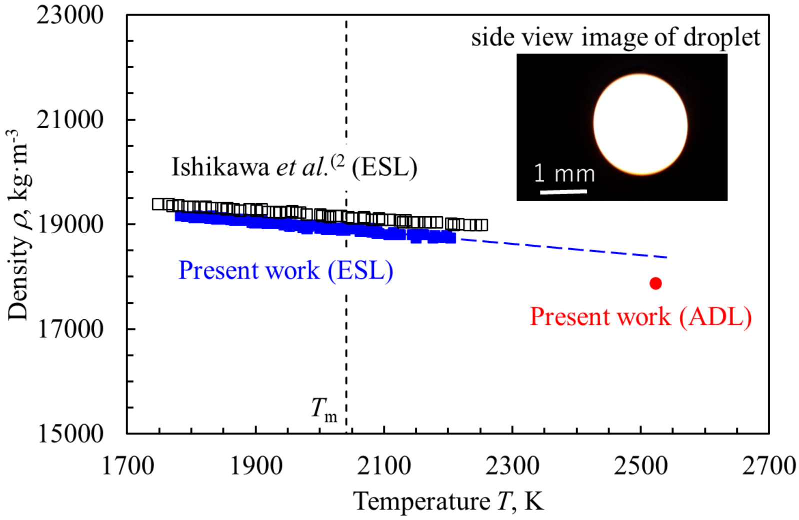

Figure 4. Density of liquid platinum measured by ADL together with those by ESL and side view of droplet just after splitting the ADL nozzle.

As mentioned above, the measurement results of surface tension, viscosity, and density of liquid platinum using ADL showed a relatively good agreement with those measured by EML and ESL. However, only one plot was obtained for viscosity and density, respectively. A continuous study should be important to conclude whether the ADL can precisely measure thermophysical properties of high temperature melt.

Acknowledgement

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References

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